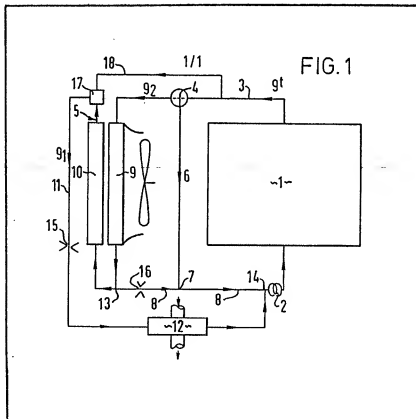


- (21) Application No 7941860  
 (22) Date of filing 4 Dec 1979  
 (30) Priority data  
 (31) 7834613  
 (32) 8 Dec 1978  
 (33) France (FR)  
 (43) Application published  
 30 Jul 1980  
 (51) INT CL<sup>3</sup>  
 F02B 29/04 F01P 3/18  
 (52) Domestic classification  
 F1B 2L40  
 F4U 24A1 24B2  
 (56) Documents cited  
 GB 1438775  
 (58) Field of search  
 F1B  
 F4U  
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(54) Cooling System for a  
 Supercharged Internal Combustion  
 Engine

(57) The proportion of the cooling  
 water from the main engine coolant  
 radiator 9 which flows through the  
 auxiliary radiator 10 to the charge air  
 cooler 12 is at least partially

determined by the flow restrictors 15,  
 16. A valve 17, operated in response  
 to the air temperature upstream or  
 downstream of the cooler 12 or the  
 compressor outlet pressure, controls  
 the proportions of coolant direct from  
 the engine 1 and from the radiator 10  
 which flow to the cooler. The  
 thermostat 4 regulates the radiator  
 coolant flow.



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FIG. 1

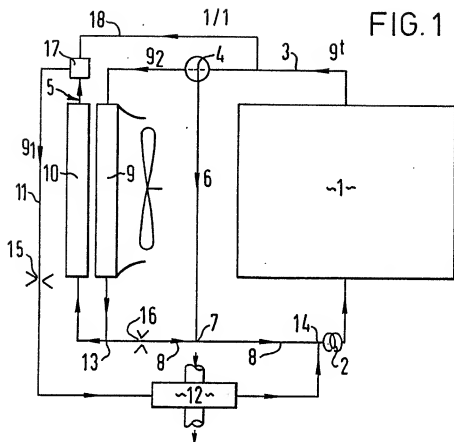
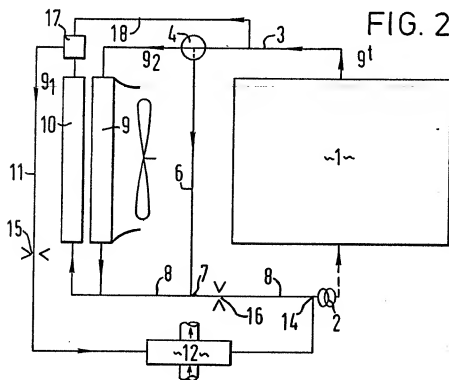


FIG. 2



## SPECIFICATION

## Cooling System for a Supercharged Internal Combustion Engine

- This invention relates to a cooling system for a supercharged internal combustion engine, including a means for regulating the temperature of the intake air of an engine which is supercharged by a turbo-compressor, which is particularly, but not exclusively suitable for engines for industrial vehicles.

- In certain areas of use of supercharged engines, and taking account of the operating conditions (ambient temperatures), the temperature of the intake air may become such that the output of the engine suffers a substantial drop and its reliability is brought into question by virtue of the high temperature level to which some parts of the engine are raised. Moreover, under low load conditions and/or at low ambient temperatures, intake air temperatures which are higher than the temperatures at the outlet of the compressor would result in substantially improved combustion and would make it possible to reduce the amount of toxic components in the exhaust gases.

- It is therefore very important to be able to regulate the temperature of the intake air to about an optimum level, independently of the load on the engine and the ambient temperature conditions.

- It has been proposed that liquid, such as water, for cooling the engine be used to cool the supercharging air. However, the water is controlled to a temperature level (75 to 90°C) such that direct utilisation thereof for cooling the supercharging air is only of limited interest, in particular for the engines which have a low degree of supercharging, as are generally employed in vehicles. In order to remedy this disadvantage, the provision of two independent water circuits has been envisaged, one being a 'high-temperature' circuit which serves to cool the engine, while the other is a 'low-temperature' circuit which is used to cool the supercharging air. Although this type of device has a very good performance, it is not used for engines for industrial vehicles for reasons of maintenance and bulk, and in particular because this kind of device requires a second water pump which makes the installation more complex and more expensive.

- The present invention makes it possible to achieve suitable regulation of the intake air temperature for engines which are supercharged by means of a turbo-compressor, including engines which have a low degree of supercharging, by using the engine cooling liquid without fundamentally modifying the design of the cooling circuit. The use of regulating means therein is reduced to the minimum degree, without compromising its efficiency in suitably regulating the intake air temperature in dependence on engine load and external ambient temperature.

In contrast to previously proposed

- 65 arrangements using the engine cooling liquid for cooling the supercharging air, the system according to the invention may be very easily used on industrial vehicles and is highly effective therein, as it is highly adapted to the continuous variations in the operating conditions in engines in vehicles.

- Accordingly the present invention provides a cooling system for a supercharged internal combustion engine including a first radiator part for cooling liquid from an engine main cooling circuit, an air/liquid heat exchanger, locatable between an outlet of a compressor of the engine and an intake of an inlet manifold of the engine for regulating the temperature of the intake air issuing from the compressor, which air/liquid heat exchanger employs cooling liquid from an engine main cooling circuit, and a second radiator part disposed in series with the first radiator part so that in use of the system some cooling liquid issuing from the first radiator part passes into the second radiator part in which, having its temperature lowered, the liquid then passes into the air/liquid heat exchanger, distribution of the liquid flows between the two radiator parts and the heat exchanger being effected in an invariable proportion by means of restriction means which are disposed in cooling liquid conduits and which are set once and for all, one being on a circuit for circulating cooling liquid in the heat exchanger and the other being on the engine main cooling circuit. Thus in the system the temperature of at least a fraction of the cooling liquid from the main cooling circuit is sufficiently reduced to be effectively used for cooling the supercharging air. This is why, in the system of the invention, the fraction of water used for cooling the supercharging air is cooled in two separate exchangers namely the first radiator part which is common to all the cooling liquid of the engine, and the second radiator part which is provided just for the above-mentioned fraction of cooling liquid. It should be noted that in the present invention the cooling liquid taken off for cooling the air is also used for cooling the engine, that is to say, the whole of the flow of liquid produced by the pump is used for cooling the engine.

- The flow regulating restriction means of the main cooling circuit of the engine preferably is disposed on the outlet of the first radiator part downstream of a connection to the second radiator part. In an alternative embodiment, the flow regulating restriction means of the main cooling circuit of the engine is disposed in the system downstream of a connection of the conduit for direct return of cooling liquid to the engine through a thermostatic valve for regulating the cooling liquid temperature of the engine, and upstream of a connection of the circuit for circulating cooling liquid in the heat exchanger, upstream of a water pump.

For a better understanding of the present invention and to show how the same may be carried into effect, reference will now be made, by way of example, in which:—

Figure 1 is a diagrammatic view of a cooling system according to a first embodiment of the invention, and

- Figure 2 shows an alternative form of the means for regulating the flow rate of such a system.

Referring to Figure 1, an internal combustion engine 1 which is supercharged by means of a turbo-compressor is cooled by cooling liquid such as water. A water pump 2 (generally driven by the engine 1) provides for circulation of the cooling water through the engine at a flow rate  $q_t$ . From the outlet of the engine, the whole of the water is taken by the conduit 3 to a thermostatic valve 4 whose opening is controlled by the temperature of the water at the outlet of the engine and which distributes the total water flow from the engine between two separate conduit lines; one of which leads to the inlet of a cooling assembly 5, while the other leads to a junction point 7 which is disposed upstream of the water pump 2 to which it is connected by a conduit 8. It will be seen that by more or less limiting the amount of water in the cooling assembly 5, the thermostatic valve 4 regulates the water temperature above a limited value of the order of 80°C, by per se known means. The cooling assembly 5 comprises two separate water/air radiator parts (10 and 9), namely, a first or main radiator part 9 and a second or auxiliary radiator part 10 which are separate from each other (or a single radiator which however comprises two separate parts with separate flow arrangements) which are disposed in series in relation to the circulation of the water to be cooled, but which are disposed one in front of the other and which have an identical cooling air flow passing therethrough, the air flow being provided by a single blower system.

As shown in the drawing, it is the auxiliary radiator part 10 which has the colder air flowing therethrough, while it is the main radiator 9 which is first supplied with water to be cooled. The water to be cooled coming from the thermostatic control at a flow rate  $q_2$  passes through the radiator 9 in which it is cooled, being reduced in temperature from temperature TS to temperature TE2; in accordance with an essential feature of the arrangement, only a fraction of the water flow  $q_2$  passes through the second radiator 10.

The water which has thus passed through radiator 10 at a flow rate  $q_1$  is reduced to a temperature TE1 which is lower than temperature TE2, and is passed by means of a conduit 11 to the intake of a supercharging air/water exchanger indicated by reference 12 and which is positioned relative to the circulation of the intake air between the compressor and the inlet air manifold of the motor (the exchanger 12 can be integral with the inlet manifold). Depending on the temperature difference between the water coming from the radiator 10 and the air coming from the compressor, the intake air is found to undergo cooling to a greater or lesser extent, while, in the limiting case, the air is heated in

passing through the exchanger 12. After having passed through the supercharging air/water exchanger, the water is returned to point 14 on the conduit 8, immediately upstream of the water pump 2. The fraction of the flow  $q_2$  of water to be cooled, which is not returned towards the exchanger 10 and then to the exchanger 12, is passed through the conduit 8 to the intake of the water pump.

- In accordance with the invention, the flow  $q_1$  of water to be cooled, which circulates in the circuit comprising the radiator 10 and the exchanger 12, is a constant fraction of the flow  $q_2$  of water to be cooled, which circulates in the radiator 9, and the ratio between the flow rates is determined by the relative values of the resistances to flow of the liquid, of pressure drops, in the following sections:

—from point 13 to point 14, and comprising the radiator 10 and the exchanger 12;

—from point 13 to point 7 on the conduit 8 returning the water to the pump.

A precise ratio between the flows,

$$\frac{q_1}{q_2}$$

- can be obtained and definitively maintained, by providing for accurate relative calibration of the resistances in the two sections referred to above, by making use of the restriction means 15 and 16 which are disposed respectively in the two sections mentioned above, namely 17 to 14 and 13 to 14. The selection of the ratio

$$\frac{q_1}{q_2}$$

results from an optimum compromise between a good level of efficiency in the exchanger 12 and water temperatures which are sufficiently low at the intake of the exchanger 12 for severe operating conditions of the engine (full power, high outside temperature), the flow rate  $q_2$  then being equal to the total flow  $q_t$  passing through the engine.

- In accordance with the invention, the system has a mixer valve 17 which is disposed on the conduit 11 between the radiator 10 and the exchanger 12 at a point which is connected to the conduit 3 (outlet of the engine) by a conduit 18. Opening of the valve 17 is controlled, by any known means, by the temperature of the intake air at the outlet of the supercharging air/water exchanger (or the temperature of the air at the intake of the exchanger or the pressure of the air at the outlet of the compressor, etc), which makes it possible for hot water which comes from the engine and which is used for reheating the supercharging air to be taken in at the intake of the exchanger 12.

An alternative form of system according to the invention is shown in diagrammatic form in Figure

2. This arrangement differs from the Figure 1 system only in that the flow of water through the radiator 10 is independent of the flow through the radiator 9, but is a constant fraction of the total flow passing through the engine. It is the relative calibration of the restriction means 15 and 16', bearing in mind the resistances or pressure drops in the other parts of the above-mentioned sections of the systems, which determines the constant fraction referred to above.

Both of the above-described systems may have a thermostatic valve at the outlet of the radiator 9, which is controlled on the intake temperature at the outlet of the water/air exchanger 12, providing for finer distribution in respect of the flows.

Thus, this construction provides for cooling of supercharged internal combustion engines comprising temperature regulation of the intake air by means of a single auxiliary radiator.

The exchanger 12 for cooling the supercharging air is supplied by means of a water circulating loop circuit 11 at a temperature regulated by a mixture of water taken from the outlet 3 of the engine and colder water taken at the outlet of an auxiliary radiator 10 which is itself supplied with water which has already been cooled, issuing from the main radiator 9 of the engine, with the loop circuit returning to the main cooling circuit 13 and 8 upstream at 14 of the circulating pump.

#### Claims

1. A cooling system for a supercharged internal combustion engine including a first radiator part for cooling liquid from an engine main cooling circuit, an air/liquid heat exchanger locatable between an outlet of a compressor of the engine

and an intake of an inlet manifold of the engine for regulating the temperature of the intake air issuing from the compressor, which air/liquid heat exchanger employs cooling liquid from the engine main cooling circuit, and a second radiator part disposed in series in the first radiator part so that in use of the system some cooling liquid issuing from the first radiator part passes into the second radiator part in which, having its temperature lowered, the liquid then passes into the air/liquid heat exchanger, distribution of the liquid flows between the two radiator parts and the heat exchanger being effected in an invariable proportion by means of restriction means which are disposed in cooling liquid conduits and which are set once and for all, one being on a circuit for circulating cooling liquid in the heat exchanger and the other being on the engine main cooling circuit.

2. A cooling system according to claim 1, in which the flow regulating restriction means of the main cooling circuit of the engine is disposed on the outlet of the first radiator part downstream of a connection to the second radiator part.

3. A cooling system according to claim 1, in which the flow regulating restriction means of the main cooling circuit of the engine is disposed in system downstream of a connection of the conduit for direct return of cooling liquid to the engine through a thermostatic valve for regulating the cooling liquid temperature of the engine and upstream of a connection of the circuit for circulating cooling liquid in the heat exchanger, upstream of a water pump.

4. A cooling system for a supercharged internal combustion engine, substantially as hereinbefore described with reference to Figure 1 or Figure 2 of the accompanying drawings.